FIELD WORK IN GEOLOGY AND PHYSICAL GEOGRAPHY

IN the March and April numbers (1896) of the SCHOOL REVIEW I published an article on "The Teacher's Outfit in Physical Geography," in which field work was urged as a most important part of the rational methods of teaching the subject. As a result of this suggestion some correspondence followed with teachers who were interested in the idea. From this I learned that many who would like thus to improve the work did not know just how it could be done; and that many seem to think that some remarkable features must be at hand in order to carry out the plan.

In consideration of a certain apparent desire on the part of many teachers for more specific suggestions I have prepared the following paper in which I have purposely chosen very simple cases,[1] most of which will be possible for all teachers. These are, of course, merely taken as types to illustrate a method, and many better illustrations could be found by most teachers. Once knowing what is possible, the only difficulty will consist in the brief time open to this class of work.

Excursion 1 shall be a collecting trip, where the object is to obtain as many minerals, rocks, and fossils as possible. It may be to a quarry, or a mine, or through a ravine, or a railroad cutting. I will assume that it is to a stream bed within the region occupied by glacial drift. In the bed of the stream are numerous pebbles and bowlders washed from the rock walls and the drift banks. The teacher makes a collection and so does each of the students. No one is to obtain more than one of a kind and all are to try to obtain as many as possible. No name is

[1] It may be said that each one of these imaginary excursions is based upon a possible excursion within two miles of the Ithaca (N. Y.) High School, and most of them within a mile of the school.

given by the teacher to any of the specimens, but each student takes his collection back to the school. There each one is described carefully and fully, and then by comparison with a labeled collection they are named. All of the work is done by the student, and by it he is trained in seeing, thinking, and concluding for himself. This can be followed by any amount of identifying of unlabeled specimens, grouping of like kinds, noting resemblances and differences, etc. If a single locality cannot be found where several varieties are close together the method used in making collections of plants can be employed. In a glacial country many and often all common rocks and many minerals and fossils can be found in a single part of a stream bed.

The second excursion is to the same creek, where the stream is cutting at the base of a clay bluff a typical exposure of glacial drift. The pupils are told to explain the deposit and they are appalled by the magnitude of the task. Some have heard that it is glacial material, and they venture the suggestion. What is the proof? None is advanced. It can be made plain that the first step toward proof is the gathering of fact. So they begin the study of the conditions, and soon are called together for a statement of the results of their observation. It is a clay bank; not entirely, but with pebbles and bowlders from the size of a pin head to a hundred pounds' weight; the pebbles are angular, perhaps smoothed and scratched on one or two sides; they are not all alike, but of various kinds; and some of the kinds have never been seen by any of the class in any of the neighboring ledges.

The teacher volunteers the information that the home of many of the pebbles is miles to the north. Now in what possible ways could a mass of material be transported for miles and left in a bank? The answer is, wind, water, and ice. A vital objection to wind is the size of the pebbles. Water rounds and assorts materials, depositing them in layers according to the velocity of the current. A current that would carry a bowlder weighing a hundred pounds would not deposit a mass of clay.

It may be suggested that floating ice dropped the bowlders, but even then there should be some assortment or stratification in the clay bank. Then ice only remains. Do the facts agree with this theory? They do in every respect, and so it may be considered a fact itself.

Then the teacher can tell something about the glacial period —the other reasons for believing in its existence, something of its extension and work, etc. Such an exercise as this will make the glacial period a reality and will sharpen the interest of the pupils, besides giving them some training in seeing and thinking for themselves. To gain this the student must be led to inquire and then to answer his own queries.

Again we go to the same creek for another and third excursion. A little down stream from the last locality the creek is cutting into a gravel bank, and just below this it has reached the shale rock through which it has cut a gorge. What is the cause of the gravel bank? Here again look for the facts. There is an assortment and an arrangement in layers. Pebbles of small size and various kinds are present, but they are rounded and there are no scratches. All causes but water can be eliminated, and this be shown to be in strict accordance with the facts. Compare with the present stream bed, in which the same conditions are found, even to a mixture of various kinds of pebbles from the glacial deposits; and the ice is probably indirectly responsible for the variety of pebbles. This study can be followed by a statement of the condition of the melting ice, the floods of water, the varying currents, and the abundant supply of rock fragments furnished by the ice.

Do these deposits bear any resemblance to any of the rocks previously found in the stream bed? Yes, the sandstone and conglomerate pebbles. How do they differ? This leads to a consideration of consolidation of sedimentary rocks. Perhaps one vent of the gravel bank is consolidated. Why? Water passing along has deposited a cement of lime or iron which has loosely bound the fragments together. Near by is a spring. Its water is hard, or it is charged with iron, some of which is

deposited as the water slowly runs away. Here is the key to the cementation of rocks. Underground water dissolving and depositing binds the rock particles together and makes sand into sandstone. The two are otherwise alike, and no sharp line can be drawn between them. The class can be told that the shelly beaches of the Florida coast are soon consolidated into a loose-textured rock, out of which houses may be built.

Going down stream to the gorge in the shale we find another lesson. The rock wall of the gorge shows an irregular face. Observation is directed to this face with the result that the irregularities are seen to extend horizontally, and that the sheets or beds are found one on another. The different layers vary in texture, but any single layer is moderately uniform in structure. Is there any resemblance to the gravel bed? Merely in the condition of horizontal layers. Of differences there are several. The layers of the sand bank are unconsolidated, they are very variable in texture and irregular in form. The reason for the consolidation of the shale is greater age, and perhaps the contact of gravel and shale can be seen in order to show that the shale is below. In any event fragments of the shale will be found in the gravel. What would cause the difference between the coarse and irregular sand beds and the slight irregularities of the shale stratification? The pupils can easily be led to show that only variations in rapidity of currents can be held accountable.

If time permits the joint planes can be studied and fossils can be collected from the rock. Later study of these shows the marked difference between them and the animals of the present. Here in this cut we have sedimentation with accompanying stratification, the entombment of fossils, an illustration of the fact that the lowest beds are the oldest, the induced structure of jointing, and at the contact of the shale and gravel an unconformity. What a wealth of illustration, and what possibilities in the training of observational powers!

Without exhausting the geological treasures of the little creek we may make a fourth excursion to it, going over the same

ground as in the last one. The stream has cut into the bluff of clay which is every once in awhile sliding down, so as to leave a fresh exposure constantly open to the air. Near the surface the clay is yellow, while below this it is blue. Here the surface waters have percolated into the dense clay and changed some of the iron to the yellow rusted form. This is one of the first steps in weathering. The roots of trees are seen extending into the soil at the top, and they are aiding in the work. The wind must blow fragments from the surface when it is dry; and that rain is wearing it away is plainly seen by the gullying of its surface.

Walking down stream a few yards a pebble is found with a roughened surface. Examining it, the indentations are found to exist where fossils are enclosed in the shale. Here is another lesson in weathering. Have a search made for similar illustrations in other pebbles. One of the larger granite bowlders is moss covered, and this agency of plants in weathering is there well illustrated.

At the gravel bank it is found that the material stands at a lower slope, and that it is more readily crumbling down under the attack of the weather than is the more dense clay bed. Thus we have an illustration of the influence of texture.

Going to the shale bluff we find that it stands nearly vertical because it is more compact than even the clay. What are the signs of weathering in the shale bluff? Why do some layers project while others retreat inward from the faces? What agents will aid in these results? What conditions in the rocks influence the weathering (joint planes, bedding planes, weak cement, easily decayed fragments, looseness of texture, etc.)? What are the differences between the weathered surface and the unweathered interior? Here we may see the importance of frost and of water which may even be seen slowly seeping out from a joint plane crack, or from a more porous bed. On the minor projecting ledges, and upon the top of the bank, the importance of vegetation is easily and clearly seen. The roots are seen entering the rock crevices, and a tiny plant torn from

the rock wall brings with it pieces of the shale. I am certain that an afternoon spent in such a study as this will do more toward interesting the pupil and giving him a rational knowledge of weathering than weeks of recitation and reading about this great process. It leads also to a consideration of the soils and their relation to the rocks—a relation not shown here, because the ice has removed it and left a glacial soil instead.

The possibilities of our creek are so far from being exhausted that I propose even a fifth visit to it. This time we go to the base of the gravel bluff, from which we can look down into the shale gorge. Through the trees on the right a gently sloping hillside rises to a divide a mile distant and at an elevation of 500 feet above the creek bed. The problem is to see how a valley two miles wide and 500 feet deep has been cut out of the shale by the tiny stream.

In the first place can any other explanation be advanced for the valley? It may be of glacial origin; but this is not possible because it extends diagonally to the direction of ice motion, and its tributaries of the same form enter it at various angles. Great floods may have washed it out; but floods would hardly have cut out a series of arborescent streams over all the country and still have left no signs of their presence. Perhaps the valley is one of faulting, but against this is the fact that the shale layers extend uninterruptedly across the valley. Possibly the surface has gaped or cracked open without vertical movement on the two sides. There are no signs of this and no reason for believing it. We know of no such cracks now forming or recently formed. If they have existed they have left us no evidence of their existence, and it is strange that the tributaries and main stream should have valleys which meet exactly as do those of rain-born rills on a road or on a beach. Each of these theories has been suggested for river valleys by former geologists, and some of them were long held and strenuously defended; but now they have no supporters, for long and careful studies in various parts of the world have proved their insufficiency.

At present the stream is so narrow that it can be crossed

with a jump, and so shallow that it can easily be waded. What is it doing? So far as we can see, nothing. Even sand and clay are undisturbed by the gentle current. However, the water is "hard," and this shows a perceptible amount of chemical load. Every cubic foot of water is carrying its load of dissolved mineral obtained from the bed and the banks. There has been no rain for days—then where does the water come from? A spring emerging from the base of the gravel hill near by shows the source of the permanent water supply and also of some of the load of dissolved mineral matter. This may be followed by a discussion of the importance of underground water.

Is this present quiet condition of the stream a permanent one? All have seen the raging torrents of spring and summer when the water is laden with mud; and at our very feet the large rounded pebbles of the stream bed are witnesses of former violence. So at times the stream is a powerful worker, and it is always doing a little work. What would result from this alone? Naturally a deepening of the valley along a rather narrow line not a great deal wider than the high-water stream breadth. Meandering slightly widens the valley and this is shown both in the clay bank and the gravel bank at the base of which we are seated. Then how did the valley gain a width of over two miles at the top? Here comes in the action of weathering and the application of the knowledge gained in the last excursion. The close of the glacial period during which the gravel bank was formed is estimated at from 5000–15,000 or more years ago. In all this time denudation has not succeeded in removing a low deposit of loose sand. Then how much more vast has been the time required to carve out and broaden into maturity a valley as great as that in which the creek runs! Granting the necessity of the explanation, the student gains from this excursion a more nearly adequate conception of the immensity of geological time and the grandeur of the result obtained by moderate action with plenty of time than he could possibly hope to get from mere reading.

The creek is flowing slowly in a rather broad amphitheater

enclosed by drift hills; then just below us it has entered a gorge in the shale and is leaping over the bed in a series of falls. Why is this change? The evidence at hand shows that the preglacial valley is partly obscured by glacial deposits through which the stream is cutting a channel, but not always directly over its old bed. Where it enters the shale it was turned over to one side of the old valley, and so is cutting a gorge in its old bank. This narrow gorge, therefore, shows a young valley which may be contrasted with the great preglacial valley. At the falls erosion is rapidly proceeding, but weathering has hardly had time to accomplish notable results. This part of the excursion furnishes abundant opportunity for amplification, and also for a statement of the development of river valleys, and of the effect of the glacier upon stream courses. Both here and in later class-room work these observations furnish a chance for frequent reference in illustration of many points which come up from time to time in the recitation or lecture.

We could make the sixth excursion to the same creek, but will follow a road which leads up the side of another one. A pair of level-topped terraces face the stream. What is their origin? They may be built up in lake water by a damming of the stream; or they may represent ancient flood plains at a time when the stream carried more water; or they may have been cut out by the stream when it was larger; or the cutting may have been done by a stream of the present size which has meandered from one terrace base to the other.

Going on a short distance we see a series of three lower terraces on one side of the stream and none on the other. A cut by the road shows that the top of one of these is composed of coarse cobble stones like those in the stream bed. Looking at the structure of the large upper terrace we find it to be made of bowlder clay. This disposes of the first two explanations, for they would demand stratified water deposits. Moreover, the top of the terrace slopes down stream, and hence is not a lake deposit, and its surface is too irregular for a flood plain. It is therefore a case of excavation; but was it done by meandering,

or by a constantly decreasing stream? The cobble deposit on the top of one of the terraces would favor either theory; but the absence of the smaller terraces on one side of the stream would stand opposed to the theory of decrease in stream volume. A little farther on we see an abandoned curve of the stream at the base of the main terrace of the right bank, while the stream is now cutting in at the base of the opposite terrace. Going still further we see other illustrations of a similar construction of terraces, and we thus gain facts favoring the one theory rather than the other, but not absolutely disproving the less favored explanation. It is well that this is so; for science abounds in problems which are now exactly in this stage. We have not yet been able to prove everything, and early instruction is entirely too apt to confuse theory and fact. Many a student has learned as a fact an explanation which he later learns to be a very insecure theory. Even scientific men are sometimes thus confused, to the detriment of scientific progress; and it is well early to impress the fact that there is yet much to learn and much that is only partially understood.

Our seventh and final excursion is to the shore of the lake which extends north and south, and we proceed along its eastern side. There are some high bluffs of shale here and low over on the opposite shore. From this we learn the greater power of the west winds, and we see the action of the waves in undermining the cliff. At the base of the cliff is a beach of shale pebbles now in the mill of wave action; but there is no clay such as would be produced by grinding shale fragments together. It has gone off into the lake and is helping to fill it up. In a little bay we see plants growing on the bottom and at its head a swamp, illustrating the agency of vegetation in lake filling.

A short distance beyond is a projection into the lake, a delta at the mouth of a stream which is filling the lake more rapidly than the mere wave action. The delta is dry and well above water, and one of the reasons for this is seen at the shore where the waves of some storm have piled the fragments to a height

several feet above the lake level. A second reason is that in time of flood the stream overflows its delta and builds it up, raising it higher on the landward side because it is nearest to the source of the water and gravel. The stream cuts the delta into two unequal parts, flowing on the northern side. Again an effect of the strongest prevailing winds which drive the delta materials to the southward.

So far the pebbles of the beach have been well-smoothed but flat bits of shale. We now come to a beach where the pebbles are rounded in form and varied in kind. Looking to the shore we see a low bank of bowlder clay in place of the shale bluff. Here is a river valley buried beneath glacial drift, a common feature in many glaciated regions. The cause for the variety and roundness of the pebbles is discovered in the glacial deposit. We could go along the shore and find other features, but probably enough has been said to indicate the class of work that seems most generally available and desirable.

I have not attempted to enter into difficult or unusual field illustrations. They are much better left until after a simpler beginning has been made. I would urge simplicity rather than complexity, for the complex is much better understood when based upon a well-formed understanding of simple phenomena.

Many who read this may say that the localities described above cannot be duplicated in their vicinity. This is very true; and yet there is hardly a place in the country where similar if not the same phenomena are not at hand. Until one has looked carefully around him with this idea in mind he can hardly realize how many really excellent and simple illustrations of geological and physiographic facts and principles are on every hand. Even the water that runs from the gutter of the schoolhouse has a lesson for study. So I would urge as the first principle of field work that the teacher should spend some time in careful study of his own neighborhood. If he does this he will meet with success in his search, wherever he may live; and then, if he will follow the method indicated, he will teach more real geology and physiography than the text-book can impart. Let him find some

places for excursions, arouse the interest of his pupils, lead them on to observation, discovery, and sound reasoning, and he will make of this part of his course a study worthy of a place in the secondary school.

As a final word of suggestion I would repeat what I have said in a previous article. Avoid turning the field day into a picnic; but in the attempt to avert this evil do not err by going as far in the opposite direction. Keep the mind constantly alert and direct the bright and the dull along the difficult path which leads to the power of individual seeing and logically concluding. Become a severe but friendly critic, ruthlessly pointing out fallacies or incorrect observations; but then follow the destructive criticism by a leading suggestion. The result of the study may be one of discouragement or encouragement according to the attitude and tact of the teacher. If the former results, then harm is done and the work had better be abandoned; if the latter, then encouragement is followed by eager interest which may even amount to enthusiasm. This result and the training that necessarily goes with it is certainly worth an effort; and if the science of geology and physical geography are going to maintain a place in the curriculum, they must establish for themselves some claim for recognition besides the mere mass of information which they impart. The claim is easy to establish, and all that is needed is intelligent effort on the part of the teacher; and given this it will soon be found that these subjects have merits of their own, so important and unique that the secondary-school curriculum that does not contain them has an important gap unfilled.

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